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The infrastructure of markets: From electric power to electronic data

Canay Özden-Schilling

Departments of History, Anthropology, and Science, Technology, and Society, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Corresponding author: Canay Özden-Schilling; e-mail: ozden@mit.edu

Following the partial deregulation of the electricity industry in the 1990s, a number of electricity markets were instituted in the United States. As relatively new experiments, electricity markets open up possibilities for anthropologists to see markets as infrastructures of information. I argue that making markets in electricity has been a project in reorganizing information relationships, transferring the burden to organize information onto market actors, making them into data processors and the markets themselves into infrastructures of information. This article is part of a yearlong multilocale ethnographic project that seeks to understand how traders, analysts, engineers, and economists make markets in electricity in the United States. It draws on 5 months of participant observation at a market intelligence company that produces data and databases and sells price forecasts to traders in the deregulated markets of electricity. It maps the work practices of data cleaning and maintenance—a kind of labor I call "database work."

Keywords Electricity; Markets; Information; Infrastructure; United States

In an upper-floor office of a Boston skyscraper, I sat on my desk with Google Earth open on my computer screen. As I dragged the view pressing a mouse button, my eyes followed a high-voltage transmission line in an unpopulated part of Ohio. At times, the line became indistinguishable from its crowded surroundings; at other times, the path that was cleared of trees to make way for the line helped me spot it again. My eyes hurt from squinting and my wrists from repetitive motion. Finally, the line entered an electrical substation: one of the thousands of nodes in the United States where electricity can be withdrawn and injected at different prices. This must have been Cedar Grove, a substation that I had seen featured in market reports for having high electricity traffic and high prices. I returned to the spreadsheet running behind Google Earth and entered its coordinates. Developers in the office would later map the spreadsheet onto a price visualization instrument. Hundreds of more rows waited to be populated, but taking a peek out the window, I saw that the sun was already setting on the Charles River. Most developers and analysts had already left the office. When developers would incorporate my spreadsheet into the price visualization instrument, which analysts would then use in daily price predictions, my tiny datum could influence a trader's buying and selling decisions, along with the direction and price of electricity somewhere, sometime. I saved my spreadsheet to return to it the next morning and stretched my wrists.

If infrastructures are "matter that enable the movement of other matter" (Larkin 2013:329), the electric grid, at first, seems to be an infrastructure of steel and copper that enables the movement of electrons. What is less visible to the naked eye, however, is the movement of money enabled by computational processes. Since the deregulation of the electricity industry in the 1990s and the emergence of electricity markets in the 2000s, the movement of money among multiple actors has been enabled by an "infrastructure of information": electronic communication networks between buyers and sellers, data organization technologies, and the work of new actors such as traders, market analysts, and other information workers. What I call "database work," as in the preceding snapshot, entails an endless, often tedious process of generating data and making them usable in computer models to keep the various actors that exchange electricity in computational tandem. Scholars of science and technology studies have defined infrastructures of information as sets of devices and codes that organize information in ways that enable geographically dispersed actors' coordination and action (Bowker and Star 2000; Star and Ruhleder 1996). In this article, I ethnographically depict electricity markets from the standpoint of their database workers and make a case for seeing contemporary markets as infrastructures of information.

Infrastructures are shot through by "forms of political rationality" (Larkin 2013:328). They equip different actors with different kinds of access to ownership and decision-making mechanisms, whether they organize the flows of water (Anand 2012), oil (Appel 2012; Mitchell 2011), or data (Edwards 2014). Through deregulation, a technique largely associated with neoliberalism (Harvey 2005), the kinds of actors and levels of access in infrastructures are reconfigured. Following Stephen Collier's (2011:243) call to move away from accounts of top-down and wholesale neoliberal change, I suggest exploring deregulation and market making as processes through which economic expertise is transformed and redistributed to new actors. When the electricity industry was deregulated, the burden of information organization and decision making was taken away from central planning authorities and granted to traders, analysts, and database workers equipped with computational tools. The electric grid's refashioning in the image of a market corresponds to the expansion of "government through the calculative choice of individuals" (Collier 2012:195) onto a previously centrally managed infrastructure, in line with Michel Foucault's (2008) descriptions of American neoliberalism. I argue that to understand this neoliberal transformation, there is no need to categorically distinguish between steel, copper, and data. With that in mind, I suggest extending the infrastructure analytic onto markets and studying them as infrastructures of information.

Market intelligence companies specializing in electricity emerged in the early twenty-first century as part of the transition toward decentralization in information relationships. In this article, I draw on 5 months of participant observation as an intern in a market intelligence company that produces data and databases and sells price forecasts to electricity traders.[1] Although electricity markets are now premised on the neoliberal idea that market actors know their supply and demand conditions better than anyone else (e.g., see Hayek 1945), and that these conditions are reflected in the form of bids and offers submitted to markets, everyone plugged into the grid is operating on messy data, usable rather than perfect information, looking for opportunities of arbitrage and speculation. This article begins with a brief history of deregulation seen as a project of the reorganization of information relationships. I then draw on my fieldwork experience to show the kinds of work practices and expertise that maintain the infrastructure of information on a daily basis. Through a study of the deregulated electric grid, I aim to explore the making of infrastructures as markets and of markets as infrastructures.

Deregulation: A project in reorganizing information

Over the course of the twentieth century, the multiplicity of providers of different scales that arose in the early days of electrification in the United States was replaced by territorial monopolies of private corporations. These corporations were nominally regulated by states, the regulation of which they effectively escaped by being larger in size than states and wielding lobbying power (Rudolph and Ridley 1986; Hirsh 2002). Under the regulation regime, corporations were granted by states the right to act as "natural monopolies" (i.e., in principle, they used economies of scale to provide lower costs than could be accomplished through competitive markets).[2] They were vertically integrated, providing all three services of electricity in their territory: generation, transmission, and distribution. Some of them had come together to make up power pools to share their transmission networks, when they thought it was more profitable to do so. Since the 1990s, we have been in a new era—that of deregulation and markets in electricity, brought about by congressional action.[3]

The Energy Policy Act of 1992 and the subsequent orders (Nos. 888 and 889) by the Federal Energy Regulatory Commission (FERC) in 1996–97 aimed at implementing deregulation in two ways: by (a) breaking up the vertically

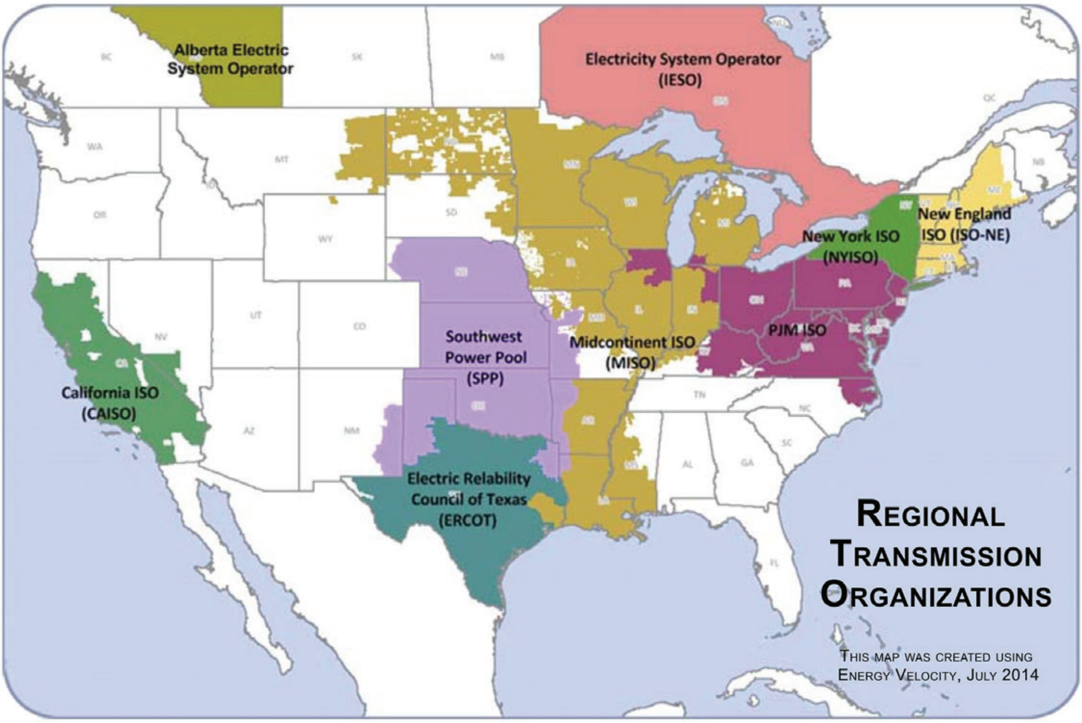

Figure 1 Map of ISOs and RTOs in North America. From http://www.ferc.gov/industries/electric/indus-act/rto.asp.

integrated holdings into functionally separate generation, transmission, and distribution providers and (2) building independent system operators (ISOs) that also act as organized exchanges where the price of 1 MW/hr of electricity is determined by market participants' bids to buy and offers to sell electricity. The act and the FERC orders allowed states to require the unbundling of holdings and previously formed power pools to become ISOs. FERC defined ISOs (and, later, regional transmission organizations, or RTOs[4]) as nonprofit organizations that operate the transmission network while not owning it. They were to act as marketplaces as well: The participants in their territories were to submit bids and offers through an Internet-based system. In deregulated states, power pools previously formed by private utilities refashioned themselves as ISOs and RTOs throughout the 1990s and 2000s and were approved by FERC as such. Today, there are seven ISOs/RTOs[5] covering parts or all of 43 states in the United States.[6] An ISO's territory can be a state (e.g., Texas's ISO, named ERCOT) or a region (e.g., ISO – New England) (see Figure 1).

Although new generation and distribution companies in states that have adopted deregulation can now enter the business and compete with the incumbent monopolists, the situation is different with transmission. Also called the "electric grid," the transmission network is what is commonly referred to as the electric infrastructure. It is made up of high-voltage transmission lines, transmission towers, transformers, and substations: the equipment that carries electricity from the plants where it is produced to the utilities that buy it on behalf of ratepayers. In an effort not to duplicate the electric infrastructure, the act and the FERC orders left transmission in control of the incumbent transmission owners (though now unbundled from generation and distribution). But transmission owners could now be required by states to open up their networks to any generation and distribution companies that might want to use them. To facilitate this, in 1996, FERC defined an information-sharing environment called the Open Access Same-Time Information System (OASIS), which is an Internet-based system where all requesters see and reserve transmission lines. Prior to deregulation, monopolists with exclusive rights of operation in demarcated territories did not have a use for shared information environments. Deregulation rearranged, not the transmission equipment of the electric grid, but the information relationships around it.

Although an ISO is usually hosted in an unmarked building somewhere in its service territory far from urban centers, a variety of market actors are plugged into its control room through OASIS. These are generation and distribution companies—or rather, the traders that they employ, who place bids and offers on behalf of their companies from their trading floors. At the outset, the ISO can appear like the central planner imagined and detested by neoliberal founder Friedrich Hayek. After all, the decision of who should produce how much electricity at what price is announced by the ISO. But the ISO fashions itself as a clearinghouse for bids and offers. In a way that would make Hayek proud, market participants are assumed to know their supply and demand conditions better than anyone else and to reflect these conditions in the form of bids and offers submitted to ISOs in various intervals. The system operators at the ISO then compute these into hourly prices binding for every participant. The computation, at the outset a commonplace marginal pricing algorithm, also adjusts for the differences in demand to buy or sell in particular locations. If more actors are interested in buying or selling near an urban center in a way that makes transmission lines load more (or "congest," in electricity market parlance), the prices of injecting and withdrawing into that line will be higher.

Traders in the world of deregulated electricity markets are makers of prices and processors of information. To predict how the ISO will compute prices and bid or offer accordingly, traders must study a variety of factors that go into price making—demand, supply, and congestion. To get a hold on demand, they must study weather, because consumers' electricity usage depends largely on weather conditions. To get a hold on supply, they must study the age, capacity, and fuel type of various generators and predict how much and at what price they will be willing to offer 1 MW/hr of electricity. To get a hold on congestion, they must study the properties of the electric infrastructure, for instance, how much power specific transmission lines are able to hold. But how do market actors conduct these studies and make these predictions? Anthropologists of trading in other (especially financial) markets have repeatedly pointed at the market actors' ethos (Ho 2009), cultural idioms (Abolafia 2001; Knorr-Cetina and Preda 2006), perceptions of time (Miyazaki 2003), and personal networks (Beunza and Stark 2003) as organizing features of markets. In this article, I am interested in another organizing feature that has received less attention: the database work that assists traders in studying and predicting. By database work, I mean generating, cleaning, and collating data to make them usable in computer models.

As part of my ethnographic research on electricity markets, I conducted a 5-month internship in spring 2013 at the Boston office of a company that I will call EnTech,[7] a market intelligence company that sells price predictions and trading strategies to traders. EnTech has viewing privileges on OASIS but does not have traders and does not conduct trading; instead, the analysts at EnTech, about 20 men and women in their twenties and thirties, who are often former or future traders, do all that a trader needs to do, except carrying out the actual trade: studying and predicting. In these tasks, they are heavily supported by in-house developers who program the proprietary computer models that the analysts run and maintain the databases (of weather, historical supply, historical demand, etc.) on which these models draw. Developers, approximately 10 men and women who are self-taught or college-educated programmers, engage in never-ending database work. Not all of this work requires skill in computer programming: When there is simply too much database work for the developers to manage, mathematically underqualified interns with free time on their hands, like me, come to the rescue.[8] To be sure, it is common for traders to do database work, program, and trade all at the same time. Although my study of the EnTech floor makes it easy to distinguish these separate tasks that are often conducted elsewhere by the same people, my goal is to comment on the broader state of the infrastructural activity undertaken by analysts and traders in electricity.

I contend that information is an anthropological subject and not a signal from a world external to humans, as economists of information from various convictions often imagined it (cf. Hayek 1945; Stiglitz 2002). The process to make data acquire an external and objective, or putatively "raw" (Gitelman 2013), character is lengthy and complex.

In electricity markets, many information collection and transmission processes center on prices, but prices are merely one among many sets of "market devices" that actors work with (Callon et al. 2007) in the larger information infrastructure (or cyberinfrastructure; Bowker et al. 2010) that standardizes representations of electric power and turns the power into a commodity tradable at a distance.[9]

What follows is a look at electricity markets from the desk I occupied in one of the upper floors of a skyscraper in Boston overlooking the Charles River. As is the case in many urban centers, in Boston, the equipment that is more familiarly considered to constitute the electric infrastructure, such as transmission lines, towers, and substations, is not readily noticeable to the city's everyday denizens. The electric infrastructure more often constitutes the background of suburban and rural landscapes. In the context of an infrastructure of information, traders can buy and sell electricity across approximately 2 million square miles of territory,[10] through equipment that they will probably never see. An infrastructure of information is what makes and maintains markets in electricity.

Between knowledge and data: On the analysts' floor

Every weekday, I emerged out of a long elevator ride, greeted the receptionist, and walked through the analysts' floor before getting to my desk in the developers' cubicles. The analysts sat on long, shared desks: Those who worked on the same ISO sat in close proximity to each other either on the same or neighboring desks. Each analyst had headphones and at least three monitors facing him or her, often supplemented with tablets and laptops and cluttered with Post-it notes. In the mornings, the floor was eerily quiet, especially in comparison with the commotion of the afternoons. As their fingers worked busily on their keyboards, the analysts did not take their eyes off of their many screens, even when those who worked on the same ISO huddled to puzzle over an image or a spreadsheet on one of their screens. They looked at the pricing model on their screens, designed by in-house developers to mimic ISOs' own pricing models. The models showed thousands of rows and columns with predicted prices at the different nodes of the grid. They were attached to databases—a mass of spreadsheets—of anything related to price making: weather, historical demand, and historical supply, among other things. Those databases had to be put together by developers using public and proprietary sources.

As a part-time intern, my time was only loosely pegged to market timelines. But analysts arrived at 6:00 AM or earlier, recalibrated their models with the prices published on ISOs' websites the day before, and put a report out to send to traders, usually around 9:00 AM. This is because every ISO has a deadline in the morning for bid and offer submission to the "day-ahead market," the ISO process by which the next day's buyers, sellers, and hourly electricity prices are determined and published in the afternoon (exact time varies by ISO). Because a big chunk of the trade settles in the day-ahead market, analysts at EnTech focus on making it to the deadline in the morning. Most days, I showed up in the afternoons, when the stress of the morning was relieved and I could get analysts and developers to answer my questions more freely. Most analysts would leave around 3:00 PM in the afternoon, when I still had a couple more hours of spreadsheet maintenance work ahead of me.

As I would be brewing yet another pot of coffee in the kitchen, analysts would be wishing me a good night. There were always some other analysts lingering on the floor well past the closure of the day-ahead market, studying their data quietly on their own. They desired to be more prepared when the next day, time turned into real-time.[11] The phrase *real-time* is not merely a figure of speech in electricity markets: It refers to the real-time markets operated by ISOs for market participants who did not get scheduled in the day-ahead market because either their bid to buy was lower than the ISO's price or their offer to sell was higher. In real-time markets, although the intervals vary by ISO, the bids, offers, and announcement of prices are closer to the moment of electricity's actual injection from a generator into the grid. Between day-ahead and real-time markets, traders always keep their desks open. Some analysts at EnTech were former traders who wanted to escape the stressful work hours of trading. Others were gearing themselves up for a future job as a trader—more stressful but higher paying. Analysts at EnTech were young people who often knew little about electricity markets until their first day on the job. More important than their bachelor's degrees in related fields like economics and various kinds of engineering, they brought their programming background to the job, along with a vague interest in energy.

"I would cost a lot of people a lot of money if I were doing your job," I once joked to an analyst, because I'm just not a morning person. "Well," he said, "you'd have to drink a lot of coffee in the morning." On another occasion, a developer who used to be an analyst told me that new analysts arrive early and stay late to study the market manual with the help, of course, of a lot of coffee. Several others highlighted that an analyst (or a trader, for that matter) needs to develop alertness and the ability to recall and mobilize several sources of information quickly. Common to these opinions is a tendency to locate the necessary skills for the job in the person of the analyst. "If all the analysts got hit by a bus one day, we would be done for, we would have to start from scratch," the same developer said to explain the dependency of developers and the company in general on analysts' accumulated experience or tacit knowledge (Polanyi 1966), while also hinting at the pedagogical processes through which this knowledge passes on to new analysts (cf. Collins 1985). At EnTech, it is commonly accepted that expertise is embodied by analysts and sustained by the commercial-sized coffee machine in the kitchen.

At the outset, this should not be surprising to anthropologists. In an effort to demystify market activities, sociologists and anthropologists of markets have studied markets as cultures, systems of meaning and belief made up of social ties (cf. Beunza and Stark 2004; Elyachar 2005; Zaloom 2006) and cultural idioms (cf. Knorr-Cetina and Preda 2006). For instance, sociologists Daniel Beunza and David Stark (2004) call arbitrage an "art of association," again placing the emphasis on traders' individual abilities. They recognize that today, access to information itself does not necessarily provide competitive advantage, because "as increasingly more information is almost instantaneously available to nearly every market actor, the more strategic advantage shifts from economies of information to socio-cognitive processes of interpretation" (Beunza and Stark 2004:372). My interlocutors at EnTech, then, seemed to agree with Beunza and Stark and with the dominant paradigm in the social studies of markets.

Watching analysts trickle into the developers' cubicles every afternoon to collectively examine the predictions they made in the morning, I decided it would be misleading to conclude the story of electricity markets here. Traders do not subscribe to EnTech's services only because of the analysts' interpretative skills. EnTech's promise to traders is that these interpretative skills are supported by a team of developers, whose work is less constrained by market timelines. The same former analyst and current developer told me, "When a trader is screaming at you on the phone, the last thing you want to do is go back and organize your data." Developers provide the extra time to calculate and refine—the kind of time that analysts and traders do not have. Whereas the interpretative work of traders, or their embodied *knowledge,* has received a good amount of attention in the social studies of markets, the infrastructural activity associated with interpretation, that is, *data* processing, is understudied.[12] The "economies of information" that Beunza and Stark have construed as passé are only beginning to be explored.

ISOs publish electricity prices on their websites and information about their transmission equipment. They also publish their own estimations of demand. All this sounds like good news for market actors. Analysts and traders need information, and information is up online. The bad news is that information is never raw and databases are always messy. For reasons that I detail in the next section, information takes a lot of maintenance work to become usable in models—maintenance work conducted by a variety of people ranging from electrical engineering PhDs to programmers and even mathematically underqualified people like me. "Information is there," as a developer told me, "you just want to automate it." Unfortunately for database workers, though, the work to automate cannot be automated (or fortunately, if it amounts to continued employment). No matter how many steps of a computer model are automated, there is always someone designing, checking, and maintaining the automation.

The *New Palgrave Dictionary of Modern Economics* (Durlauf and Blume 2008), the ultimate goal of which "is to represent the late-20th-century state of economics to the educated world" (Solow 1988), has no entry for the word "information." Another esteemed economics dictionary, the *MIT Dictionary of Modern Economics,* reroutes the reader under the entry for "information" to the entry for "perfect information." Information has been an elusive concept and one of the more loaded terms in the history of economics. And "perfect information" is a thought exercise in the context of a discipline that has experienced the information revolution only in the postwar period, significantly later than many natural sciences (Mirowski 2002).

Information imperfection is a constant condition of opportunity and possibility for analysts and traders alike: If they had a guiding ideal, it could not be further away from perfect information. The collectors and processors of information, be it the ones who treat it as a commodity and sell it, like EnTech, or who use it directly for profit, like traders, seek the competitive advantage of partial and exclusive information. Analysts and traders are information-processing actors who depend as much on database making and maintenance work as they do on interpretative and associative skills. In fact, as media scholar Lisa Gitelman and Virginia Jackson (2013:3) put it, "the imagination of data entails an interpretive base." If analysts and traders had a guiding ideal, it would be the perfect database. Alas, the perfect database also remains elusive.

Database work: In the developers' quarters

Most days, I arrived in the office in the afternoon and bypassed the analysts' floor to head straight for my desk in the developers' cubicles. My ritual was to turn on my computer, log into the shared computing environment of the company, and log into Skype. In the quiet quarters of the developers, I would sometimes sit for the entire afternoon without talking to anyone, occasionally lifting my head over my two monitors to take a peek at the Boston view. If you watched me work, you could think my "screenwork" (Boyer 2013) was unsupervised. In fact, if you watched anyone in our quarters work, you could think the work here was solitary. But within the computing environment, we were all connected. Tasks were assigned, findings were entered as comments, and the feed showed who was working on what. My supervisor sat in an office in the Midwestern United States: We were part of a team of five, three of whom were interns, who worked on a new product, a real-time map of transmission flows. We discussed the tasks over Skype's instant messaging interface. Occasionally, I did delve into solitary work, cleaning data on spreadsheets for hours on end. I would stay later than analysts, along with some developers, and get teased for "burning the 5:00 PM candle." But even then, I knew that my supervisor would vet my spreadsheet the next morning. Until approved, my work was simply a comment entry; once approved, it was data.

As scientific disciplines and commercial technologies have become more and more dominated by a phenomenon called *big data,* social scientists have turned their attention toward the meanings of data and widely criticized the implications of assuming *datum* to mean a "given," that which precedes a fact (Rosenberg 2013). Scholar of information infrastructures Geoffrey Bowker wrote that "raw data is both an oxymoron and a bad idea: on the contrary, data should be cooked with care" (Bowker 2008:184). In the edited volume inspired by this quotation and titled *Raw Data Is an Oxymoron,* scholars have documented how different disciplines imagined and generated data—or, following Bowker's term, "cooked" them (Gitelman 2013).

Though I agree with the central premise of this argument—that there is labor to generating data—I also think there is something to be said about the process of generating data to appear and be accepted as raw. Here I draw on the way sociologist Michel Callon (1998) analyzes markets. To critically address the assumptions of economics about markets, Callon argues, we do not need to dismiss them as unreal; to the contrary, we should pay attention to the processes by which they are made real, more or less successfully. For the parties and stakes of a market transaction to take place, humans and things need to be disentangled from their various associations and framed in a way that fits into economically accepted categories. Objects, for instance, need to be disentangled from their past histories to become exchangeable properties. Farmers need to be disentangled from their crop to become parties to a transaction. Callon argues that what is to be studied in markets are these processes of framing and the unexpected new associations they create.

Similar processes of disentanglement take place in market databases. It is not only the analyst who takes it on to herself or himself to distill all the information on his or her three monitors into neat-looking reports; database workers also aim to condense the multiplicity of messy bits in numeric and textual formats into cells on a spreadsheet. In electricity markets (at ISOs and EnTech alike), databases are representations of the electric infrastructure: They are electronic data representing the flows of electric power. And database workers frame these representations in a way that can factor into pricing models programmed by developers and fashioned after ISOs' pricing models.[13] This process requires a weeding out of all associations that will not be accounted for by models—such as the past histories of current equipment and current controversies around them. Equipment is represented by variables relevant to price making, such as its fuel type, generating capacity, age, and location.

The real-time map of transmission flows that we worked on visualized the transmission infrastructure of the United States to make it easy for subscribed traders and in-house analysts to see which direction power was flowing and in what amounts—both important kinds of data that go into congestion and hence into price making. The product had a sleek interface that in-house programmers had designed. On my first day, my supervisor remarked to me how pretty it looked. The transmission lines were depicted in different colors to make them easy to distinguish. Once you hovered over a line with your mouse cursor, a dialogue box would appear with the amount of power flowing on that line at the moment—although only if we had that information through public or proprietary sources. At the time, the map had few lines on it: The goal for our team was to populate the map with new lines and new kinds of information about those lines that can be potentially useful to traders and analysts, such as their power-carrying limits (which factor into congestion). The equipment's location and line limits first had to be there on the database; only then could new real-time information be incorporated (or "scraped") from sources and appear on the map. So we set out to map the electric infrastructure onto spreadsheets.

This project may seem as ambitious as that of the imperial cartographers in Borges's 1946 short story "On Exactitude in Science." In that tale, cartographers make a map that is the same size as the territory they hope to chart, with, in the end, the map eventually becoming the territory itself (also see Baudrillard 1988). Unlike those fictional cartographers, no one has ever put together a complete database of the electric infrastructure, including the ISOs. All actors have partial knowledge of the infrastructure, which they represent differently. Take PJM Interconnect: The largest ISO in North America, PJM is headquartered in Pennsylvania and covers all or parts of 13 states. The spreadsheets published on the PJM website include the names, code names, and voltages of various equipment, such as transmission lines, substations, and transformers. These spreadsheets exclude any information about the line limits or locations of these devices, partly because PJM has no perfect knowledge about the properties of the equipment either. Equipment gets old, its properties change, it gets replaced or removed, all of which make it hard to capture it in a database. Transmission is supervised by PJM but divided into territories, each operated by a transmission owner. Each one of PJM's spreadsheets is devoted to one transmission owner and has stylistic differences, if not an altogether different convention. Whereas lines are given names closer to plain English in the territory of one owner, another one has chosen to be more cryptic with names. And given that PJM has approximately 10,000 transmission lines and more substations, collecting, standardizing, and squeezing all these data into one database is a lofty goal. So where does one start?

Where one does not start is the perfectionist attitude of Borges's imperial cartographers. Echoing the electricity traders I had interviewed who favor action over inaction at any cost, the team members wanted the product to be useful right away and not necessarily complete or perfect. The definitions of useful information on the floor applied to this product too: It is useful if it assists analysts and traders in predicting prices while being easily cognizable. Database work is necessarily a selective process. We started by accumulating the higher voltage lines whose code names appeared frequently on ISOs' congestion lists: Those were the ones "the customers wanted to see," because the prices around them fluctuated more, opening up possibilities of profit. Selection continues as the database is being expanded as well. We left the equipment that did not readily factor into our models—at least for the time being.

My supervisor reminded that we would eventually want to have everything in the database. But my coworkers were often quick to remind me that "everything" was a figure of speech—a guiding ideal.

In the absence of a database for equipment location, I spent hours on end on GoogleEarth, visually following transmission lines and substations to find their locations, which I then exported to a spreadsheet in the form of GPS coordinates. Short of going to each location and seeing for ourselves, flying over and hovering on the digital Earth of Google was the next best thing. As a database worker, I connected the dots I collected using Google's different tools. Using the web search tool, I collected textual information about the equipment we wanted to have in the database. This information included everything ranging from official announcements by constructing and operating companies, to reports of citizens unhappy with infrastructural constructions, to expert reports used in siting permission processes and (where those processes have failed) lawsuits. While looking for the landmarks that the equipment might have been named after, I became familiar with the host communities of the electric equipment in states I have never physically visited. My clues existed to end in GPS coordinates—and to be revived in another search later.[14] My supervisor sent me tasks for equipment in a corner of Ohio, for instance, because I had "been in the area for a while." As I was virtually transported to Ohio, analysts were tuned in to the local time and weather of their ISOs' service territories. Our being in Boston was incidental—we only remembered it when yet another snowstorm was about to strike New England and we showered the in-house meteorologists assisting analysts with questions about local weather.

This disembodied engagement with the electric infrastructure is characteristic of electricity markets. Digital representation enables traders to buy and sell electric power remotely. A virtual trader (a trader with no assets who makes profit by way of speculation) from Maine, for instance, can trade in Texas, or in any one of the seven ISOs for that matter, provided the trader registers with ERCOT, the ISO of Texas, and has a steady Internet connection. Digital representation empowers market actors, but not all of them and not equally. The fact that digital representation can work through the collection of public data should not veil its exclusivity. The handling of public data, in electricity markets, requires the time of database workers and the skill of programmers. What is published by ISOs as public data are merely bits, valueless until processed onto databases and analyzed by models, which only select actors like traders and market intelligence companies are qualified to do.

What is found through the web search tool of Google is no different. For instance, news of a new power plant in a particular location can signal that prices there will go up or down—but unless the properties of the plant are acquired and entered into a model, this bit of information is close to useless. Finally, all of us who are part of electricity markets as captive ratepayers cannot process these data, nor would it matter for us to do so, because we are removed from ISOs' and FERC's decision-making processes. The "public" of public data is an exclusive bunch. It is preceded by an overlooked "infrastructural history" in which information is patched together from unevenly distributed sources (Helmreich 2011) and succeeded by equally overlooked processes of unevenly distributed capacities to make sense and use.

The challenges facing the perfect database are many and often silly. There is "metadata friction" (Edwards et al. 2011) between the various databases at EnTech and elsewhere due to reasons as mundane as homonymous equipment and misspellings. There are simply too many streets and landmarks in the United States named Cedar Grove and almost as many equipment pieces named after them. Looking for a transmission line on a spreadsheet to no avail often resulted in the line being spelled in yet another way by an ISO or a transmission owner employee. While learning to anticipate how certain common words were likely to be misspelled in particular regions, we also had discussions of automating misspelling detection. Here again, however, the automation had to be preceded by defining what misspelling was, which proved close to impossible in the face of the misspelling creativities we encountered.

Contacting an ISO representative for the clarification of public information is always a possibility, though the process yields varying results. After consulting EnTech's in-house analysts of PJM and developers with backgrounds in electrical engineering, our team still struggled to figure out what the code "RAD" in front of some line names meant, and I finally clicked on the live chat button on PJM's website. After being referred to one representative after another for half an hour, one representative finally got back to me reporting that "RAD" stood for "radial line" in PJM parlance. As I ran by him our understanding of what a radial line was, that is, a line that carries power in only one direction, he said, "Correct," and added honestly, "as I understand it."

Database work in the midst of all this data friction is a collective process. Circling around equipment for hours on GoogleEarth, collecting textual and numerical clues—at times, nothing seemed to work to help us find what we were looking for. A line we had been searching for for hours could turn out to be an underground line, impossible to see on GoogleEarth or on the other satellite maps to which we resorted in regions where GoogleEarth's aerial photos were far from up to date. If we wanted to have the location of that equipment in the database to be able to scrape public data released about it, we simply had to compare best guesses and drop the pin on one spot. As my supervisor reminded frequently, it was "better to have something if not the exact perfect thing." Once the best guess was agreed on, the bit went into the database, and once the database was refreshed in the server, the bit was set to appear on the map: It had become data. It was made raw; it contained exactly as much as would be usable in analysts' models, no more, no less.

Developers who dealt with much larger databases of thousands of rows (such as historical demand) reminded me playfully that whatever I entered as data would remain as data. It was not that often that databases were controlled for quality. Yet our team still preserved the hope that in the future, with better clues, we would go back to the database and make data more precise. The database, it turned out, had a temporality, too, just like the markets it supported (Miyazaki 2003). The temporality of the database is often nonlinear.[15] Once, while importing data from both the textual and geographic annotations of the same subscription-based database, I noticed discrepancies and slightly panicked to learn from a team member that the geographic annotation on which I was mostly relying was an older version. Upon reassuring her that I would now rely on the newer, textual version, she advised not to assume that older necessarily meant less perfect. She had seen cases of older databases being preferred by developers. The nonlinear progression of database work is what keeps database workers alert and constantly at work.

What does database work mean for the nature of expertise in contemporary markets? Does a trader, analyst, or developer have to know anything about the physics of electric power to operate in the market? The question of trader expertise received quite a bit of interest in popular literature after the 2008 financial crisis, especially the proliferation in financial markets of quantitative analysts specializing in physics and math (cf. Patterson 2012). Anthropologists have also explored the question of how and if market actors cultivate familiarity with commodities and financial instruments. A successful fish merchant needs to master the conditions of perishability and exchangeability of each fish (Bestor 2004); a dealer in the booming business of Islamic mortgages needs to be conversant with Islamic jurisprudence (Maurer 2006). Conversely, it is also true that the world's major cotton traders have no interest in cotton as an organism or crop (Çalişkan 2010) and that the creators of financial instruments in investment banks pass their new creations imperfectly onto back-office employees charged with keeping these instruments alive (Lepinay 2011). What may result is unequal access to decision-making mechanisms, which is often disproportionate to familiarity with the commodity in question, and at times, with market failure.

At EnTech, a few developers were electrical engineering PhDs whose engineering expertise was sought sporadically. When an ISO's terminologies or a piece of equipment's features were obscure, their expertise became valuable. But they were first and foremost program developers, who had the advantage of having a better understanding of the logic of ISOs' algorithms. Their electrical engineering background was useful, but secondary. Vertically integrated utilities and other large companies with assets still employ electrical engineers as traders. But just like in other markets, people who have less familiarity with the commodity in question are increasingly able to plug into the market as programmers and database workers.

Digital databases signify continued efforts to represent electric power in the form of electronic data in a way that disentangles market actors from electric power. The conventions of representations, of course, are not arbitrary and require electric power and electronic data to be fundamentally connected. Those conventions, such as ISOs' price-making algorithms, are in fact created with the contribution of power systems engineers, as I explore elsewhere in my research. But once the disentanglement takes place, it becomes possible for database workers to treat electric power, that elusive source of power, just like any other tradable commodity.

Conclusion

Of course, electric power is not just another commodity. It cannot be imported from overseas, for instance, like electronics, or stored in large quantities, like oil.[16] The commodification of electric power has created different political and social relationships from the ones that, for instance, sugar has (Mintz 1986), and still different ones in the United States (Nye 1999) from the ones in Zanzibar (Winther 2010). If the making and meanings of different commodities are subject to anthropological inquiry, so is the process to make them the equivalent of one another—the social mediation through which yarn and iron get price tags and become exchangeable (Marx 1973; Simmel 1990)—and the process to make goods into commodities, in ways ranging from stripping them of their social meanings, which often prove obstinate (Zelizer 1997), to representing them in standard formats in shared information environments. If, in the late nineteenth century in the United States, the commodification of electricity translated into the standardization of the initially disparate ranges of voltage and frequency (Hughes 1993), in the postderegulation era, it translates into the standardization of its representations in digital databases, through a process I call database work. Making markets in electricity has been a project in reorganizing information relationships, transferring the burden to organize information onto market actors, making them into data processors and the markets themselves into infrastructures of information.

One of the most celebrated economics articles in the twentieth century, "The Use of Knowledge in Society," was written by Friedrich Hayek (1945), the devout advocate of markets.[17] There Hayek praised the system of prices for channeling all the bits of information distributed across society. The price was a semiotic wonder, according to Hayek, which condensed nothing more or less than all information relevant to a buyer or seller, and which got multitudes of people to act in a desirable way. In that article, Hayek sang the praises of the unthinking human, who nevertheless participated effortlessly in the organization of information. Instead of taking the making and maintenance of information for granted, in this article, I have described the selection of relevant information to be incorporated into prices and the methods of acting on such information—all conducted with the aid of specialized tools by specific people, neither quite unthinking nor completely masterful, people like the developers and analysts in this story. The anthropology of markets has much to gain from following them, for it is through their work that markets today are made and maintained as infrastructures of information.

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Notes

1 This article is part of a yearlong multilocale ethnographic project that seeks to understand how traders, analysts, engineers, economists, and citizens make and participate in markets in electricity in the United States. The sites where I have conducted research but on which I do not report in this article include a smart grid laboratory, an electricity market training session, and citizen group networks.

2 Samuel Insull, who headed a Chicago-based holding company including Commonwealth Edison, until it collapsed during the Great Depression, is credited as one of the most powerful businessmen advocating for the regulation of the electric industry and as being a frequent mobilizer of the term *natural monopoly.* For a biography, see Wasik (2008).

3 The history of how political will for deregulation in electricity came about has yet to be written. Journalistic accounts shed light on the emergence of new kinds of lobbyists in the 1990s, energy corporations like Enron (founded in 1985 and went bankrupt in 2001), which saw opportunities of profit in

newly deregulated markets and used political connections to bring about deregulation legislation (McLean and Elkind 2004). In my preliminary interviews, economists and engineers who witnessed discussions of electricity deregulation in the 1980s suggested that following the deregulation of airlines in the late 1970s, there was a feeling of inevitability in the air for the deregulation of electricity.

4 In addition to Orders 888 and 889 (1996), in which ISOs were defined, FERC issued Order 2000 in 1999, in which a separate but similar definition for RTOs was provided. The difference between an ISO and RTO is mainly one of scope: A larger ISO can apply to FERC and get approved as an RTO without significant consequence to its operations. In the industry, the terms are used practically interchangeably.

5 In the rest of this article, I only use the term ISO following the dominant practice in the industry.

6 However, only 16 states have yet started deregulation, meaning they require the breakup of vertically integrated utilities, and 7 other states have the process pending. (For current information, see the website of the Energy Information Administration at http://www.eia.gov/electricity/policies/restructuring/restructure_elect.html.) Therefore some states that continue regulation nevertheless fall under the purview of ISOs. Deregulation is by no means a homogeneous process, and given that every state and ISO deploys aspects of deregulation selectively, national statistics are unclear and suspect at best.

7 A pseudonym.

8 EnTech welcomed me as a doctoral student wanting to learn the functioning of electricity markets. I sought and was granted explicit permission to write about EnTech's work, subject to the terms of a mutually signed confidentiality agreement. I revealed my researcher–writer status to the employees with whom I worked: Some extended special help to explain the terms of electricity markets to me. The views and actions of the employees who might not have been alerted to my researcher–writer status are excluded from this study.

9 To be sure, electricity is not unique: Goods and services only become exchangeable, and thus turn into commodities, through a commodification process. Still, they constantly step in and out of commodity status and travel across different regimes of value (Appadurai 1988; see also Ferguson 1988).

10 This is an estimation I reached by adding the areas of the seven ISOs' service territories.

11 In his discussion of the fast pace of information management in digital journalism, anthropologist Dominic Boyer (2013:5) notes that he prefers the term *fast-time* over *real-time* to highlight the forms of mediation that disable the possibility of instantaneous connectivity. Also see Riles (2004) for a discussion of the uses of the concept of real-time in the making of technocratic knowledge.

12 For important exceptions, see Lepinay (2011) and Riles (2011).

13 For a discussion of similar processes in geostatistical representation, see Schilling (2013).

14 For a discussion of the relationship between GPS and the changing understandings of territoriality in the twentieth century, see Rankin (2011).

15 In his discussion of biodiversity, Geoffrey Bowker points out the temporality of biodiversity databases, which is constructed around the idea of "background stasis and foreground change" (Bowker 2004:108).

16 Research on grid-level electricity storage is ongoing, but its applications are currently insignificant.

17 *American Economic Review* selected this article in 2011 as one of the 20 most important economics articles of the twentieth century.

References

Abolafia, M. 2001 Making Markets: Opportunism and Restraint on Wall Street. Cambridge, MA: Harvard University Press.

Anand, N. 2012 Pressure: The Polytechnics of Water Supply in Mumbai. Cultural Anthropology 26(4):542–564.

Appadurai, A., ed. 1988 The Social Life of Things: Commodities in Cultural Perspective. New York: Cambridge University Press.

Appel, H. 2012 Offshore Work: Oil, Modularity, and the How of Capitalism in Equatorial Guinea. American Ethnologist 39(4):692–709.

Baudrillard, J. 1988 Simulacra and Simulation. Stanford, CA: Stanford University Press.

Bestor, T. C. 2004 Tsukiji: The Fish Market at the Center of the World. Berkeley: University of California Press.

Beunza, D., and D. Stark 2003 The Organization of Responsiveness: Innovation and Recovery in the Trading Rooms of Lower Manhattan. Socio-Economic Review 1(2):135–164.

——— 2004 Tools of the Trade: The Socio-Technology of Arbitrage in a Wall Street Trading Room. Industrial and Corporate Change 13(2):369–400.

Bowker, G. C. 2004 Time, Money, and Biodiversity. *In* Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems. A. Ong and S. Collier, eds. Pp. 107–123. Malden, MA: Wiley-Blackwell.

——— 2008 Memory Practices in the Sciences. Cambridge, MA: MIT Press.

Bowker, G. C., K. Baker, F. Millerand, and D. Ribes 2010 Toward Information Infrastructure Studies: Ways of Knowing in a Networked Environment. *In* International Handbook of Internet Research. Pp. 97–117. New York: Springer.

Bowker, G. C., and S. L. Star 2000 Sorting Things Out: Classification and Its Consequences. Cambridge, MA: MIT Press.

Boyer, D. 2013 The Life Informatic: Newsmaking in the Digital Era. Ithaca, NY: Cornell University Press.

Çalişkan, K. 2010 Market Threads: How Cotton Farmers and Traders Create a Global Commodity. Princeton, NJ: Princeton University Press.

Callon, M. 1998 Laws of the Markets. Malden, MA: John Wiley.

Callon, M., Y. Millo, and F. Muniesa 2007 Market Devices. Malden, MA: Blackwell.

Collier, S. 2011 Post-Soviet Social: Neoliberalism, Social Modernity, Biopolitics. Princeton, NJ: Princeton University Press.

——— 2012 Neoliberalism as Big Leviathan, Or? A Response to Wacquant and Hilgers. Social Anthropology 20(2):186–195.

Collins, H. 1985 Changing Order: Replication and Induction in Scientific Practice. London: Sage.

Durlauf, S. E., and L. E. Blume, eds. 2008 The New Palgrave Dictionary of Economics. New York: Palgrave Macmillan.

Edwards, P. N. 2014 A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming. Cambridge, MA: MIT Press.

Edwards, P. N., M. S. Mayernik, A. L. Batcheller, G. C. Bowker, and C. L. Borgman 2011 Science Friction: Data, Metadata, and Collaboration. Social Studies of Science 41(5):667–90.

Elyachar, J. 2005 Markets of Dispossession: NGOs, Economic Development, and the State in Cairo. Durham, NC: Duke University Press.

Ferguson, J. 1988 Cultural Exchange: New Developments in the Anthropology of Commodities. Cultural Anthropology 3(4):488–513.

Foucault, M. 2008 The Birth of Biopolitics: Lectures at the Collège de France, 1978–1979. New York: Palgrave Macmillan.

Gitelman, L., ed. 2013 Raw Data Is an Oxymoron. Cambridge, MA: MIT Press.

Gitelman, L., and V. Jackson 2013 Introduction. *In* Raw Data Is an Oxymoron. Lisa Gitelman, ed. Pp. 1–14. Cambridge, MA: MIT Press.

Harvey, D. 2005 A Brief History of Neoliberalism. New York: Oxford University Press.

Hayek, F. A. 1945 The Use of Knowledge in Society. American Economic Review 35(4):519–530.

Helmreich, S. 2011 From Spaceship Earth to Google Ocean: Planetary Icons, Indexes, and Infrastructures. Social Research: An International Quarterly 78(4):1211–1242.

Hirsh, R. F. 2002 Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System. Cambridge, MA: MIT Press.

Ho, K. 2009 Liquidated: An Ethnography of Wall Street. Durham, NC: Duke University Press.

Hughes, T. 1993 Networks of Power: Electrification in Western Society, 1880–1930. Baltimore: The Johns Hopkins University Press.

Knorr-Cetina, K. D., and A. Preda 2006 The Sociology of Financial Markets. Oxford: Oxford University Press.

Larkin, B. 2013 The Politics and Poetics of Infrastructure. Annual Review of Anthropology 42:327–343.

Lepinay, V. A. 2011 Codes of Finance: Engineering Derivatives in a Global Bank. Princeton, NJ: Princeton University Press.

Marx, Karl 1973[1857] Grundrisse: Foundations of the Critique of Political Economy. New York: Random House.

Maurer, B. 2006 Pious Property: Islamic Mortgages in the United States. New York: Russell Sage Foundation.

McLean, B., and P. Elkind 2004 The Smartest Guys in the Room: The Amazing Rise and Scandalous Fall of Enron. New York: Penguin Books.

Mintz, S. 1986 Sweetness and Power: The Place of Sugar in Modern History. New York: Penguin Books.

Mirowski, P. 2002 Machine Dreams: Economics Becomes a Cyborg Science. New York: Cambridge University Press.

Mitchell, T. 2011 Carbon Democracy: Political Power in the Age of Oil. New York: Verso.

Miyazaki, H. 2003 The Temporalities of the Market. American Anthropologist 105(2):255–265.

Nye, D. E. 1999 Consuming Power: A History of American Energies. Cambridge, MA: MIT Press.

Patterson, S. 2012 Dark Pools: High-Speed Traders, AI Bandits, and the Threat to the Global Financial System. New York: Crown.

Polanyi, M. 1966 The Tacit Dimension. Chicago: University of Chicago Press.

Rankin, W. 2011 After the Map: Cartography, Navigation, and the Transformation of Territory in the Twentieth Century. Ph.D. dissertation, History of Science, Harvard University.

Riles, A. 2004 Real Time: Unwinding Technocratic and Anthropological Knowledge. American Ethnologist 31(3):392–405.

Riles, A. 2011 Collateral Knowledge: Legal Reasoning in the Global Financial Markets. Chicago: University of Chicago Press.

Rosenberg, D. 2013 Data before the Fact. *In* Raw Data Is an Oxymoron. Lisa Gitelman, ed. Pp. 15–40. Cambridge, MA: MIT Press.

Rudolph, R., and S. Ridley 1986 Power Struggle: The Hundred-Year War over Electricity. New York: Harper & Row.

Schilling, T. 2013 Uranium, Geoinformatics, and the Economic Image of Mineral Exploration. Endeavour 37(3):140–149.

Simmel, G. 1990[1907] The Philosophy of Money. New York: Routledge.

Solow, R. 1988 The Wide, Wide World of Wealth. New York Times, March 20.

Star, S. L., and K. Ruhleder 1996 Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. Information Systems Research 7(1):111–134.

Stiglitz, J. 2002 Information and the Change in the Paradigm of Economics. American Economic Review 92(3):460–501.

Wasik, J. F. 2008 The Merchant of Power: Sam Insull, Thomas Edison, and the Creation of the Modern Metropolis. New York: Palgrave Macmillan.

Winther, T. 2010 The Impact of Electricity: Development, Desires, and Dilemmas. New York: Berghahn Books.

Zaloom, C. 2006 Out of the Pits: Traders and Technology from Chicago to London. Chicago: University of Chicago Press.

Zelizer, V. 1997 The Social Meanings of Money. Princeton, NJ: Princeton University Press.